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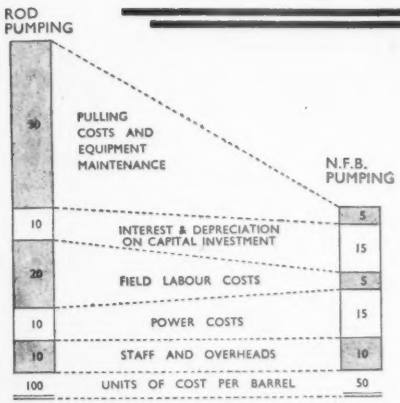

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THE FORM OF THE OIL INDUSTRY

Adapted by D. E. Doyle from *Our Industry**

INTEGRATION—the unifying of the various stages of an industry under one control or proprietorship—is a process common to many enterprises in the last few decades. The brewery owning its own public-houses, and the steel manufacturer owning his own coal-mines (before their nationalization) are but two examples. It may have evolved by producers seeking their own marketing outlets, or by the reverse method of a selling organization wishing to ensure its supplies by entering the production field. In the petroleum industry integration has developed, as it were, from both ends, and the result is seen to-day in the large international oil groups such as Anglo-Iranian, Shell, and Standard, which loom so large in it.

Especially in its producing and refining stages oil demands a large capital outlay; this is true even in a country such as the U.S.A., with well-developed communications, but even more so in the relatively underdeveloped countries to which the world is looking increasingly for its future oil supplies. In such regions the building of roads, housing and a host of other costs arise before a newly discovered field can be brought into production. In such areas large capital resources are a *sine qua non*.

This condition means that production, to pay its way, must be large. And it is this very size which provides that flexibility needed to meet changes in demand, both as regards quantity and type of product. It might be asked, for

* Published by the Anglo-Iranian Oil Co. Ltd.

example, whether the huge wartime demand for aviation spirit could have been so promptly met except by refiners with large resources. And if it had been would they have been able to reconvert to other products so rapidly after the fighting ended?

To consider now the relationship between fields and refineries, it is widely held that the latter should be located as near the former as possible, consistent with satisfactory means of transport to markets. This means that products can be dispatched by the shortest route to those marketing areas where each is in demand. It is true that this policy has been modified in recent years for considerations based on other than purely commercial grounds. But this matters less if a refinery located in a consuming, rather than a producing area, can be assured of a sufficient market close at hand.

Transport of oil, too, has a characteristic making for integration, namely that it calls for highly specialized equipment. The oil barrel carried in a railway goods-wagon has long given way to tank-cars (both road and rail), tankers, and pipelines. None of these is suitable for the carriage of miscellaneous cargoes, despite the legal status of pipelines in the U.S. as "Common Carriers". For most practical purposes they must concentrate upon one type of liquid alone (although a tanker can carry a variety of petroleum products simultaneously). It is therefore natural where an operator is handling large quantities of oil, and particularly if he is in the production, refining, and marketing fields at the same time, that he should provide himself with his own links between them, especially when by doing so, he can build them to his own requirements.

Although there are these strong factors making for integration, the process by no means covers the whole industry. Even the big groups do not refine and market their own entire production, nor conversely do they hesitate to meet some of the needs of their marketing sides by buying from convenient outside sources of supply. Again, there are plenty of small non-integrated companies to be found throughout the world, although it is only in the U.S.A. that they are at all numerous on the production side. It is perhaps interesting to note that in some markets and for certain products (of which motor spirit and kerosine are the chief) the integration process stops short of the final stage, and the ultimate consumer buys from a quite small independent tradesman, such as a garage-owner or grocer.

The U.S. Position

Historically, the industry can best be considered in two parts—the U.S.A., which accounts for roughly two-thirds of both production and consumption, and the rest of the world. The period of the American industry from 1870 (eleven years after the discovery of "Drake's Well") until 1911 is mainly the story of the rise of the Standard Oil Company to a position where it controlled 90 per cent of the pipelines and about 85 per cent of refining and marketing activity in the States. It took little interest, however, in production, where its stake was only about 11 per cent. In 1911 the Sherman Anti-Trust Act was invoked against Standard Oil, resulting in its dissolution into some thirty independent units.

The next three decades saw a great expansion of the industry under the stimulus of World War I and the growing popularity of the automobile. Newcomers were attracted, but under the pull of the economic forces which have been described above, amalgamations were frequent, until by 1939 there were about a score of firms controlling some 60 per cent of production, 70 to 80 per cent of refining, and over 90 per cent of pipelines, the balance being in

the hands of a very large number of ndependent non-integrated firms. The elatively high proportion of production till in independent hands should be oted. The legal position of oil disoveries in the U.S.A., with subsoil ights vesting in the owner of surface roperty, makes the situation of the merican domestic crude producer very ifferent from that in most other ountries, where one or a few conessionaries usually hold government-ranted rights over a large area.

Of the large American companies four re, chiefly for historical reasons, known s the Big Four, and the others as the major independents". The former onsist of the Standard Oil Company New Jersey)—biggest oil company in he world; the Socony-Vacuum Oil ompany, Standard Oil Company of alifornia, and Standard Oil Company ndiana). All originated from the old tandard Oil Company of John D. ockefeller, and within the United tates the four compete actively on the omestic production and marketing des.

The first three are also among the ading concerns outside the U.S.A., oth as producers and marketers. tandard of New Jersey and Socony-acuum are partners in a number of nportant oil enterprises abroad. Their ar Eastern interests are merged in the tandard-Vacuum Oil Company (in self a fully-integrated concern). These artners also together represent the merican element in the international onsortium of the Iraq Petroleum ompany, and in Middle East Pipelines, ormed with Anglo-Iranian to build a ipeline from Iran and Kuwait to the Mediterranean.

Standard of California similarly has n overseas partner in the Texas Corporation. The joint interests of the wo form the "Caltex" group of companies. Outstanding among these on he producing side are the Bahrein Petroleum Company with a field and refinery at Bahrein Island, Persian Gulf, and the Arabian-American Oil Company (popularly called "Aramco") operating on the Saudi-Arabian mainland. Negotiations are still in progress for the Standard/Socony-Vacuum group to acquire a 40 per cent interest in Aramco.

Another important American overseas interest is that of Gulf Oil Corporation in the Kuwait Oil Company, which it owns equally with Anglo-Iranian.

Rest of the World

Outside the U.S.A. the striking feature about oil history is how the pattern of production and distribution has changed and is still changing, so that countries which were once leaders in the international market are now virtually out of the picture, while some of the most important sources of to-day were unknown twenty-five years ago.

In the former class comes Russia, once the world's largest producer (11,000,000 tons in 1901). After a sharp decline following the revolution, she to some extent came back into the international market in the inter-war period, but consumed an increasing proportion of her own output until she ceased to count as an exporter. Roumania was also an important producing country before 1939, her properties being worked largely by the big British and American groups, but she has now been so completely drawn into the Russian sphere of influence that it is impossible to foresee when Roumanian oil will ever again appear in quantity west of the iron curtain.

Mexico in 1921 attained a production figure of 29,000,000 tons but after a long story of disturbed conditions and expropriation of foreign interests, she accounts to-day for only about a quarter of that amount. Much valuable production in the Far East has also been lost as the result of wartime destruction, and political changes in the territories have impeded its restoration.

The two areas of the world, however, which have arisen enormously in importance are Venezuela and the Middle East. In the former, annual production in the hands of several of the big international concerns, has risen from five million tons in 1926 to over sixty million to-day, making it the largest producer outside the U.S.A. With Trinidad and Columbia it makes up the Caribbean area.

Over 17,000,000 tons of Venezuelan production is controlled by the Royal Dutch-Shell group, which among the international concerns has some unique features. It is owned 60 per cent by Dutch and 40 per cent by British holding companies, and its interests include every aspect of petroleum. It has also financial holdings in U.S. producing and marketing companies. On the marketing side it sells in nearly every country of the world.

In the Middle East, the pioneer company is the Anglo-Iranian Oil Company, which has been exporting from Iran since 1912 and whose current Iranian production is over 20,000,000 tons a year. It is, as already mentioned, a partner in the Kuwait Oil Company and has widespread refining, shipping, and marketing interests outside the Middle East as well.

The Iraq Petroleum Company, with production at Kirkuk and pipeline connexions to the Mediterranean at Haifa and Tripoli, is owned jointly by Anglo-Iranian, Royal Dutch-Shell, the Compagnie Française des Pétroles, and the Standard/Socony-Vacuum group, plus a small private holding. It is thus a fusion of British, Dutch, French, and American interests. It should be noted that the company is concerned with production and pipeline operation only, the necessary refining, tanker, and marketing sides being provided from other resources of its parent companies. It is therefore not fully integrated in itself, but fits into the general pattern of integration.

It is worth noting in conclusion, that apart from the French holding in the Iraq Petroleum Company, the international oil trade is almost wholly in British, Dutch, and American hands (although the list of companies mentioned here is not in any way exhaustive). It does not seem to have attracted commercial enterprise, except in these countries, to any great extent.

WORLD POWER CONFERENCE

It has been announced that the Fourth Plenary World Power Conference will be held in London in June 1950, and that the building of the Institution of Civil Engineers will be the headquarters. The theme of the conference will be world energy resources and the production of power.

Particulars of the committees or representatives of the 39 member-countries of the W.P.C. are now available in the 1948 edition of *National Committees and Representatives*. Copies are obtainable from C. H. Gray, secretary to the International Executive Committee, 201–2 Grand Buildings, Trafalgar Square, London, W.C.2. The *1947 Annual Report* of the W.P.C. is also obtainable from the same source, price 1*s.* 6*d.*, post free.

OIL SUCTION AND DISCHARGE HOSE

THIS new B.S.I. specification (B.S. 1435: 1948) covers hose for use with all grades of petroleum products at temperatures up to 180° F. Four types of hose are specified (for 100, 150, and 225 p.s.i. working pressures and a submarine hose for 150 p.s.i.) and internal diameters vary from 2 to 10 in. Broad details of construction are given, nipples are described, and tests are specified. Copies of the specification are available from the B.S.I., 28 Victoria Street, London, S.W.1, the price being 2*s.* post free.

ANGLO-AMERICAN CO-OPERATION IN OIL MEASUREMENT STANDARDIZATION

VISIT OF A.S.T.M. DELEGATES TO EUROPE

THE visit to Europe of Messrs L. C. Burroughs and J. G. Detwiler, two prominent members of A.S.T.M. Committee D 2, began with their attendance at the inaugural meeting of the Institute of Petroleum Standardization Sub-Committee No. 1 (Measurement and Sampling) on April 22, 1948, and terminated with a recapitulatory meeting with the chairmen of the various Panels of Sub-Committee No. 1 on June 3. During this six-week period, these two gentlemen met the I.P. Panels responsible for Tank Calibration, Measurement of Oil Depths, Sampling, Temperature Measurement, and Units of Measurement, Calculations, and Tables. They also met, in company with I.P. representatives, standardization bodies in France, Belgium, and Holland, and increased their knowledge of the practical side of British and European methods of measurement and sampling by visits to various refineries.

OIL MEASUREMENT TABLES

The primary purpose of their visit was to settle the details of the contents of a proposed joint A.S.T.M./I.P. Manual of Oil Measurement Tables and to this end five all-day meetings with I.P. Panel F (Units of Measurement, etc.) were arranged. These meetings were held at intervals throughout the six weeks and there was also a discussion in Paris with representatives of various technical associations and standardizing authorities in Belgium, France, and Holland, and of various French petroleum companies. A vast amount of preparatory work was necessary between each of these meetings.

Concentrated effort by all concerned has resulted in the compilation of a comprehensive list of oil measurement tables for inclusion in the proposed manual. These tables will cover every phase of the calculation of oil weights and volumes in the American, British, and Metric systems of measurement, and the direct interconversion of measurements in these systems over a gravity range of 0·500 to 1·100. Thirty-seven tables, many of which are combinations of two or more tables, will be included in the proposed manual which will probably be published in loose-leaf form, with suitable binders available if required.

The need for authoritative tables for countries based on the metric system is obviously most urgent, and the decision was made to avoid delay in their production. While the production of the tables goes forward, additional data will be collected and experimental work is to be put in hand.

Following on the discussions on the European continent it has been decided to adopt 15° C. as the standard temperature for the metric system, and these tables will be computed so as to give results as metric weights in air in line with British and American practice. These proposals were explained and approved at the Paris meeting which was held at the head office of the Association Française des Techniciens du Pétrole, and attended by delegates from that body and from other technical associations and standardizing authorities in France, including "A.F.N.O.R.", the "Institut Français du Pétrole", the "Société de Gaugeage et de Baremage", the "Direction des Carburants", the

"Service des Instruments de Mesure", as well as representatives of various French petroleum companies, and of petroleum technologists in Holland and Belgium. Contacts with the Continental associations are to be resumed prior to the actual production of the metric tables.

The latest and most up-to-date metrological data will be used in the compilation of this manual of tables, the work of production of which will be shared equally by the A.S.T.M. and the I.P.

The final recommendations on oil measurement tables have still to receive the formal approval of the A.S.T.M., and subject to this approval, the necessary steps for the rapid production of the tables will be taken immediately. Firm decisions in printing and distribution have not yet been taken but it is likely that whilst the calculation work will be shared by the two bodies, printing of all tables will be done on both sides of the Atlantic and copies bearing joint A.S.T.M./I.P. imprint will be available from either A.S.T.M. or I.P.

Others Aspects of Measurement and Sampling

At the initial meeting with I.P. Sub-Committee No. 1, the general position with regard to the development of co-operative work on oil measurement and sampling by the A.S.T.M. and the I.P. was reviewed, and mention was made of certain special points of difficulty in connexion with the work of individual Panels which had been put down for discussion with the A.S.T.M. representatives.

During the six weeks, each of Panels A. (Tank Calibration), B. (Measurement of Oil Depths), C. (Sampling), and D. (Temperature Measurement) held a meeting which was attended by Messrs Burroughs and Detwiler. Differences between A.S.T.M. and I.P. oil measurement methods were fully discussed. The procedure used by the A.S.T.M. in publishing their "Standards" was outlined and the corresponding I.P. procedure explained.

Questions such as the expansion of tanks under oil head when calibration by internal measurement methods are used, the various applications of the use of positive displacement meters in the oil industry, and the particular need for experimental work on temperature measurement, were, in particular, fully explored.

Much constructive criticism was offered and considerable progress has been made towards attaining uniformity in A.S.T.M. and I.P. oil measurement methods.

On June 3 a final meeting with the chairmen of Panels was held and the progress achieved by the visit was reviewed. On the whole there is very little difference between the recommendations of the two bodies. The A.S.T.M. and the I.P. are however, not yet completely in agreement on the policy to be followed in writing up oil measurement methods; A.S.T.M. methods are at present more in the nature of instructions to operators, whilst I.P. methods are presented in a form suitable for use by supervisory staff. Oil measurement methods have two functions—straight instructions to operators on how the job should be done, and more general recommendations written for supervisory staff and which can be referred to in contracts. In future, two types of procedure may be needed, since in the final writing up of documents the text should cater for both the above functions. The general view at these particular discussions seemed to be that detailed and unified documents should first be prepared, and on these could be decided whether in each case a second simplified document for contract purposes is desirable and practicable.

CONCLUSION

Everything that it was hoped would be accomplished by the visit has been achieved, and the way is now clear for rapid progress not only in the production of joint A.S.T.M./I.P. oil measurement tables but also with regard to the other aspects of A.S.T.M. and I.P. co-operative oil measurement work. There can be no gainsaying the fact that these personal discussions between A.S.T.M. and I.P. representatives have indeed been most fruitful in their results.

* * * *

Since his return to the U.S.A. Mr L. C. Burroughs has written to the President of the Institute as follows:

"I am writing to express my warmest appreciation and thanks to you, and through you as President of I.P. to your associates in I.P., with whom Mr Detwiler and I were privileged to meet, for the many courtesies which made our visit to England most enjoyable and worth while.

"I particularly want to thank Mr Hyams and the members of the I.P. Measurement and Sampling Sub-committee and its panels for their generous co-operation during the many meetings. Everything that was hoped for was accomplished and the way is now clear for rapid progress not only in the production of oil measurement tables but also with regard to the other phases of joint I.P./A.S.T.M. oil measurement work.

"Mr Detwiler and I have made many new friends and feel that as a result of these meetings an even closer bond of understanding has been attained between I.P. and A.S.T.M. D 2."

In his reply Mr E. A. Evans said:

"I can assure you that we all enjoyed immensely the opportunity of giving a welcome to such pleasant ambassadors of the A.S.T.M. Your charm and grace helped enormously in consolidating the very happy relationship between the I.P. and the A.S.T.M. We do hope that we may have the pleasure of seeing you again.

"I know that Mr Hyams and his Sub-Committee were surprised at the amount of work that we were able to get through with your aid. It has given us all a great deal of encouragement to deal with the wider aspects which face the petroleum industry."

New work recently started by the **British Standards Institution** includes loading, stowing, and unloading of carbon black, and bolting material for the petroleum industry.

The 1947 **Index to A.S.T.M. Standards** lists the society's 894 standards and 553 tentatives which were in effect at December 1947. These are indexed under subjects and numerically in order of serial designation.

STAFF CHANGES

Consequent upon the resignation of the General Secretary, Mr F. H. Coe, which became effective on July 31, Mr D. A. Hough has been appointed to the post and will take up his duties on September 1.

Mr George Sell has been appointed Editor of the Institute's publications.

SCOTTISH BRANCH

Mr A. Fleming has agreed to undertake the duties of Honorary Secretary in succession to the late W. Robert Guy.

New address of the **British Tar Confederation** and **The Coal Tar Research Association** is 9 Harley Street, London, W.1 (telephone: LANgham 1778).

A VISIT TO A SCOTTISH SHALE MINE

At the kind invitation of Scottish Oils Ltd., through the medium of their managing director, Mr Robert Crichton, members of the Branches Committee of the Institute were able to enjoy the experience of inspecting a shale mine—Philpstoun No. 1, West Lothian.

Before descending the mine, the mine manager, Mr R. Keddie, explained the general layout of the mine and showed, by means of maps, the route which the party would take. Each member of the party was then provided with overalls, a safety helmet, and a lamp. It was surprising to find that the general type of lamp in use was an acetylene lamp having a naked flame issuing from the front and provided with an automatic lighter.

Those of us associated with petroleum and thinking of the dangers associated with coal mining, already began to realize that shale was something new to us. Oil shale is heavy impregnated rock of laminated structure, dark brown to black in colour, the fractured surface having a smooth, rubber-like appearance. It is not readily inflammable and does not burn readily like coal.

The oil cannot be extracted from the shale by the use of solvents but is retorted, with consequent cracking, which accounts for the difference between the properties of shale oil in its crude form and in the form in which it occurs in the rock.

The pit shaft which the party descended was not vertical but was inclined at an angle of about 1 in 3 from the horizontal. The descent was made at a comfortable speed on open trolleys attached to electrically driven winding gear. The roof of the shaft was strengthened by steel girders supported on brick walls which lined the sides. These bricks are made from waste shale and are of excellent quality.

At the bottom of the shaft we were shown the large pumps which are required for continual removal of water which would otherwise flood the mine.

The shale was being worked in seams of an average thickness of about seven feet but irregularities in the roof gave forceful demonstration of the necessity for safety helmets as we followed our guides alongside tramways through the workings. A branch to the right brought us to a main road along which full and empty trucks (or "Hutches") were being hauled. In this section the trucks were being filled from a belt conveyor extending back into the workings and which was being fed from shaker conveyors which joined it at right angles.

The belt conveyor was trough shaped, supported on inclined rollers and was made of reinforced rubber. The shaker conveyors consisted of continuous steel troughs, gently inclined and suspended by chains from pit props or supported on rollers on the floor of the working. The shaker conveyors were fed by hand at the shale face. The conveyors are driven by electric motors.

So far our journey through this giant honeycomb had been illuminated by electric light but as we advanced along the working levels we had to depend on the light from the lamps which we carried. Ventilation was good and we passed occasionally through air locks closed by wooden doors or hanging brattice cloth. On one occasion it was necessary to negotiate a very small opening which necessitated one of the stouter members of our party receiving assistance from the rear and as he struggled through he was heard to murmur, "What me, in my state of health!"

We eventually reached the face where shot holes for blasting were being drilled. Each shot hole is about 4 ft 6 in deep and is drilled in about four minutes by means of an electric drill. Blocks of blasting powder, in which powder-cored fuses are inserted, are

tamped into the holes and, after blasting, the loose shale is shovelled on to the conveyors. It is necessary for the very large pieces of shale to be broken down to smaller sizes.

The amount of dust in the workings is not excessive and is not combustible.

We were now about 300 ft below ground level and as we followed the route of the shale on its way to the winding shaft, we found that we were travelling uphill. The exercise was making us uncomfortably warm and our moist skin was accumulating a certain amount of dust. We were informed that if we so wished it was possible to walk to ground level. We did not so wish!

Before returning to the surface we were shown something of the non-mechanized parts of the mine where ponies and diesel tractors are used. We were assured that pit ponies are not blind and they certainly have clean and comfortable living quarters.

Having spent some two hours in this underground world of industry we again boarded the trolley which would take us back to the surface and after a complicated ringing of signal bells we set off with our backs to the distant spot of daylight above us.

After regaining the surface we were shown the huge ventilating fan which was drawing fresh air through the mine. We were taken through an air lock into the drift connecting the fan to the ventilating shaft and found ourselves standing in an immense wind-tunnel where the rush of air extinguished some of our acetylene lamps.

From the pit-head the full trucks of shale are hauled on a ropeway across country to the retorting centre.

The mine is situated in pleasant countryside which is unspoiled by the mining operations which extend for miles underground.

These brief impressions of a visit of unusual interest are written in appreciation of the kindness of our host Mr Crichton who, with Mr J. M. Caldwell, Mr W. Robert Guy, and Mr R. Keddie, acted as our guides, and to record the thanks of those members of Branches Committee who were fortunate in enjoying the traditional Scottish hospitality extended to them by the committee of the Scottish Branch.

SONDES PLACE RESEARCH INSTITUTE

"SUCH an organization can make a valuable contribution towards filling a gap in our present industrial research equipment. While we possess research laboratories in our large industrial undertakings second to none in the world, in addition, our co-operative industrial research associations (organized under the aegis of the Department of Scientific and Industrial Research) undertake research into fundamental and technological problems common to the industries they serve. These are a form of organization unique to Britain and which in the past thirty years have exercised a profound influence on the progressive development of British industrial practice. We have only in recent years recognized the need for an organization such as this, which will undertake, for payment, research on problems arising in the scientific and technological field of industry, the

Sondes Place Research Institute.

results of such work remaining the sole property of those who commission it," said Sir William Larke, K.B.E., at the opening, on June 18, of the research laboratory of Mactaggart & Evans Ltd., at Sondes Place, Dorking, Surrey.

Mr J. K. Michie, chairman of the Institute and of Steel Bros. & Co. Ltd., in introducing Sir William, gave a brief history of the foundation of the company and referred to the difficulty of financing an undertaking of that size. However, those difficulties had been overcome by discussions between Mr Mactaggart and Steel Bros. He hoped that the Sondes Place Research Institute would in time to come fulfil similar functions to the Mellon Research Institute.

ANGLO-IRANIAN REFINING ACTIVITIES

In his statement to stockholders, issued with the annual report of the company, Sir William Fraser, C.B.E., chairman of Anglo-Iranian Oil Co. Ltd., referred to the company's refining operations in Britain and France as follows:

Britain

"The company's refinery at Llandarcy processed 420,537 tons in 1947 against a normal capacity of 360,000 tons, this increase being due to operating adjustments, effective towards the end of the year, which will step up capacity during 1948 to the rate of 850,000 tons per annum; this figure is scheduled to rise to 3,000,000 tons per annum by the end of 1949 when the full expansion scheme for this refinery is completed. Grangemouth refinery operated at its normal maximum capacity of 360,000 tons per annum, which will be raised to the rate of 600,000 tons per annum in the current year. We have planned to increase this figure to 1,500,000 tons. In addition to these big increases in our two existing United Kingdom refineries, it is our intention to construct a large new refinery in Kent; and it is to be hoped that early approval will be given to what I feel can be regarded as an important national project."

France

"In France the L'Avera refinery of our associated company Société Générale des Huiles de Pétrole processed the record figure of 775,566 tons of crude oil during 1947, but the war-damaged Courchelettes refinery remained practically inoperative. A new refinery at Dunkirk is to be built by S.G.H.P., which has also arranged to acquire the refining licence of Raffinerie de Pétrole du Nord, a company associated with the Belgian Petrofina Group whose Dunkirk refinery was destroyed during the war. The new refinery will process crude oil for R.P.N. in addition to our own requirements, the larger quantity being handled under this arrangement giving us the benefit of more economic refinery operation and an additional outlet for crude oil."

The Institut Française du Pétrole is considering the publication of a special edition, annually or twice-yearly, of its *Revue* to be devoted to articles concerning petroleum geology (micropalaeontology, sedimentary micrography, migration, etc.). Since the cost (about fr. 500) will depend on the number of subscribers, those interested are invited to communicate with the Editor of the *Revue* at 2 Rue de Lubeck, Paris 16e.

PERSONAL NOTES

Leslie C. Beard, Jr., assistant director of laboratories of Socony-Vacuum Oil Co. Inc., has been elected a member of the board of directors of the A.S.T.M.

DOMESTIC HEATING RESEARCH

The Fuel Research Station Calorimeter Building

We were recently privileged to pay a visit of inspection of the new calorimeter building erected at the Fuel Research Station at Greenwich by the Department of Scientific and Industrial Research.

Research into the properties and utilization of domestic fuels has been carried on at the station for many years, and towards the end of the war was extended to cover new appliances. This work is being performed in co-operation with other research organizations, with Government departments, with the Building Research Station and with the manufacturers of heating appliances.

When the new work was commenced it soon became apparent that the routine testing facilities would need to be supplemented by a testing installation equipped for more elaborate investigations. The new building was then designed to provide facilities for the measurement of radiation, convection, heat to water in boiler, heat losses to stock, etc. Thus, the tests can give a picture of the behaviour of the appliance under various conditions and with various fuels.

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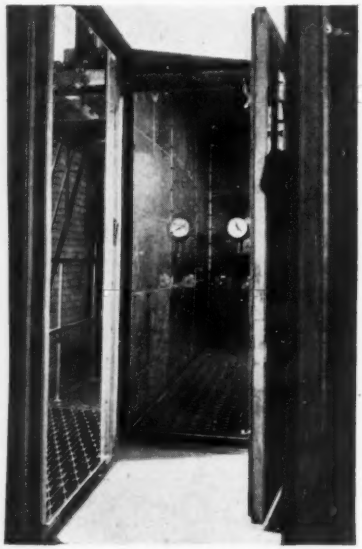
Exterior of cabinet showing wiring of thermocouples.



[Crown copyright reserved.

Entrance to one of the cabinets. The constant-temperature chamber is seen through the opening to the left.

The Calorimeter Cabinet

The main feature is the provision of air-tight calorimeter cabinets, each 12 ft square and 9 ft high, in which the appliance can be installed and operated. Each cabinet is mounted in a constant-temperature chamber, above which is a smoke-testing room equipped for smoke measurement.

The cabinets are of ¼-in plywood covered on both sides with copper sheeting in 2-ft by 1 ft 6-in sections, a thermocouple being embedded in each section. The wiring is arranged so that heat flow can be measured through any individual section or any group of sections. Air flow into the cabinet is controlled and recorded automatically.

Recording instruments and controls are brought together in the control room, which is outside the constant-temperature chamber, and comprise a six-line recording potentiometer, constant-temperature controller, remote control switches, indicator lamps, etc.

In the smoke-testing room, the smoke is measured by a beam of light projected across the flue on to a photo-cell, the output of which is amplified and fed to a recording potentiometer.

COUNCIL COMMENTARY

A VERY good number of councillors assembled on June 9 and elected Mr C. A. P. Southwell to the chair, in the unavoidable absence of the President, Mr E. A. Evans.

Before any business was transacted, Council stood for a short time as a mark of respect on the passing of Mr A. C. Adams, a founder-member and pioneer of the Institute and its President from 1927 to 1929.

Matters arising from the Minutes included a report from the Finance Committee and a tentative list of proposed membership of Council committees, submitted by the President and the Honorary Secretary.

Mr G. H. Coxon reported that the 1946 accounts would be submitted to the adjourned 34th Annual General Meeting later in the day, but that the 1947 accounts still awaited the attention of the auditors; he also reported the arrangements made for drawing the attention of oil companies to the work of the Institute.

With regard to the membership of Council Committees it was decided not to discuss the tentative list but to accept recommendations from the chairmen of the various committees.

The election committee report E.234, consideration of which had been deferred at the previous Council Meeting, was finally passed, after a lively debate round the table. These discussions are likely to continue until the new classes of membership are firmly established by precedent as well as by by-laws. Meantime, this lively interest of the Election Committee and the Council in the correctness of decisions regarding admission and grading of members is all to the good of the Institute and, in the long run, of the new members themselves.

At this point the clock indicated that the afternoon portion of the Institute General Meetings called for that day would be well under way. This doubtless accounted for the speedy acceptance, without discussion, of the report of Publications Committee. Proposals from Mr T. Dewhurst for the reception of delegates to the International Geological Congress were also accepted and it was agreed that the Institute should give a reception along the broad lines indicated.

Styrene Co-Polymers Ltd. has been formed by joint agreement between the Berger Group and the Petrocarbon Ltd./Petrochemicals Ltd. Group for the purpose of building and equipping a new factory near Partington, Cheshire, for the production of co-polymers of styrene.

THE ENGINEERING PRINCIPLES OF THE PRODUCTION OF OIL FROM PETROLEUM RESERVOIRS

By L. C. STEVENS (Fellow)

PART II*

EXPLOITATION POLICY

In this part the application of the knowledge of the reservoir gained during the "appraisal period" to the subsequent "exploitation period" will be discussed.

Sound exploitation policy should be characterized by efficient utilization of reservoir energy to obtain maximum ultimate recovery of the oil originally present in the field with minimum capital investment and operating cost. In making this statement it must be realized that the time factor is extremely important economically; thus the most efficient rate of production from the angle of ultimate recovery may prove too slow to be economic in the financial sense; on the other hand too great a density of drilling, although giving a high initial production rate, may result in adverse financial results due to overcapitalization on wells and auxiliary facilities. Hence the importance of drawing up a carefully considered plan of development for the reservoir, with regard to the density of the wells to be drilled and other important points subsequently to be mentioned, before regular exploitation commences.

The foremost consideration for the efficient use of the reservoir energy is the conservation of the gas associated with the oil. Blowing off the gas from a gas cap should be avoided and all wells should be produced at the lowest possible gas/oil ratios.

The production of water with the oil is also highly undesirable particularly in the early life of the field because, once present, it usually enters at continually increasing rates until it drowns out the oil from the well almost completely, resulting in loss of ultimate recovery. Furthermore, to lift it to the surface represents a wastage of reservoir energy or requires an external source of energy. Its subsequent separation from the crude, particularly if it forms a difficult emulsion, may add considerably to the cost of production. In the latter stages of the life of a field a certain water cut may be unavoidable, however, and by producing at the highest possible rate during this period the increased flushing action of the water may give a higher oil/water ratio than at lower rates, enabling further economic recovery to continue for a limited time.

Production policy from two contrasting types of petroleum reservoir, referred to subsequently as Type A and Type B, will be described in order to illustrate basic exploitation principles. In nature various gradations between these two extreme types are frequently encountered and will call for special consideration.

Type A.—Reservoirs having a high degree of pressure communication throughout, in which the oil can be extracted in such a manner that the maximum possible benefit can be derived from any water drive or gas cap expansion energy which are frequently available in a reservoir of this type. Actually, production proceeds by virtue of the gravitational forces tending to separate the three phases, oil, water, and gas, into distinct continuous bodies with more or less horizontal contact planes. Coarse-grained, sharp sands free from argillaceous material, cemented

* For Part I see pp. 193–9.

but fractured sandstones and cavernous and fractured limestones, usually belong to this class. Reef limestones may also be included when these have been subjected to a sufficient degree of solution or fracturing and oolitic limestone if the degree of communication is not seriously decreased by secondary cementation.

Type B.—Reservoirs characterized by a poor degree of pressure communication over the structure as a whole due to low or rapidly varying permeability. Porosity and permeability may be high locally but erratic, or correlatable zones of good porosity may occur within the main formation, but generally speaking over the reservoir as a whole, it is of a discontinuous nature. Water drive is probably absent or, if active at all, usually contributes insufficient energy to recover the oil under water drive control in an economic period of time. Rapid gravitational segregation of gas is limited by the heterogenity of the reservoir and production is mainly by depletion. Fine grained, argillaceous sands, or relatively thin sands inter-bedded with shale or separated by shale laminae, partially cemented unfractured sandstones, and most limestones of the oolomitic or intercrystalline type fall into this class. Also reef limestone, when there is no secondary porosity due to solution or fracturing, and oolitic limestones where appreciable secondary cementation has taken place.

Some specific points of oilfield exploitation practice will now be considered, bearing in mind the general principles already enunciated and the two general classes of petroleum reservoir described above.

I. Location of Drainage Points

In Type A reservoirs with a high degree of communication, relatively wide spacing of wells, of the order of one-half to two miles, will be adequate. The wells drilled for drainage purposes, commonly known as exploitation wells, should be located around the structure at such a position in the oil column that the longest possible producing life can be obtained before either the encroaching edge water or the expanding gas cap reaches them. If the height of the oil column is large compared to the thickness of the productive interval, and if it is apparent that a strong water drive is present, the wells should be situated high on the structure, for instance with their base not below the mid point of the oil column, *cf.* Well E (Fig. 1*). If on the other hand gas cap expansion is expected to predominate and water drive is absent or weak, the exploitation wells should be located so that they encounter the productive horizon in the lower half of the oil column, *cf.* Well B (Fig. 1). However, it is often the case that the oil column will decrease due to both edge water and gas cap encroachmen ttaking place simultaneously, and it may be several years after exploitation has commenced before it is possible to say which of the two will eventually predominate; in this case the initial exploitation wells should be located with the mid point of their production interval at approximately mid oil column, or staggered so that they alternate somewhat above and below mid oil column, *cf.* Wells C and F (Fig. 1).

Type A reservoirs with a thin oil column will require the application of special measures to secure maximum recovery. No definite indication can be given of the minimum height of oil column necessary for the successful application of the methods of production discussed, but in general the better the degree of communication the smaller it may be.

In the case of a Type B reservoir with limited pressure communication and depletion characteristics, it is normal to space the wells very much closer, say between 500 and 1200 feet apart, usually evenly spread over the structure in a square or triangular location pattern. It is common practice to commence by drilling a network of wells on

* See page 194.

a wider spacing than that which it is believed from consideration of the reservoir characteristics to be the optimum distance and then, depending on the results achieved and the evidence of the ability of the reservoir to sustain a higher withdrawal rate, to drill a second net of wells at intermediate points between the intial "primary" spaced wells. This "secondary" net of wells would, of course, be modified to exclude areas of particularly low productivity or where small secondary gas caps may have formed or where the likelihood of a certain amount of edge water encroachment is apparent.

II. Completion Depth of Wells

All wells are normally drilled right through from top to bottom of the productive formation, particularly in Type B reservoirs. In Type A reservoirs this may be mechanically impossible, due to loss of mud circulation, e.g. in a highly fractured limestone, or it may be undesirable to penetrate the lower part of the productive zone in order to avoid completing too close to edge water, *cf.* Well B (Fig. 1). Similarly in wells drilled through or near to the gas cap, the upper part of the productive zone may be cemented off behind casing, *cf.* Well E. Adjustment of the offtake zone in producing wells may subsequently be found necessary due to the advance of either edge water or gas cap and this possibility should be allowed for in the casing scheme adopted.

In fractured or cavernous limestones it is very important that drainage wells should as far as possible be placed so that their chances of entering the most permeable section of the lime are considered favourable. Fracture zones are often related to the major lines of faulting and every effort should be made to establish the position of such trends. Fig. 2 illustrates a field in which most wells have been completed in or close to faults.

III. Rate of Production

In Type A reservoirs the most important consideration is to maintain even encroachment of the oil/water and oil/gas interfaces at all times. In other words, the creation by uneven withdrawals of large variations in the hydrostatic pressure gradient from point to point over the structure should be avoided. Also the production of gas in excess of the solution gas/oil ratio should be prevented for as long as possible. In a Type A field with a relatively high oil column, producing wells situated reasonably deep in the oil column can be produced at high rates, without the flowing pressure at the top of the producing interval falling below the saturation pressure of the crude. This will exclude the possibility of excess gas being withdrawn from the producing wells; gas liberation, due to drop in reservoir pressure, will take place in a zone of bubbling liquid just below the gas/oil interface. The free gas will migrate to the upper part of the reservoir, where a secondary gas cap will form and the energy of its further expansion can be utilized.

The more permeable the reservoir and the greater the height of the oil column above the top of the productive formation in a particular well, the higher the rate at which it can be produced and still satisfy the aforementioned conditions. If the gas segregation in a vertical direction is very rapid, it will even be possible to produce at pressures somewhat below the saturation pressure without the gas/oil ratio exceeding the solution figure. The degree to which this is permissible can only be determined by experience.

In a depletion type field (Type B) an increase of the gas/oil ratio above solution ratio cannot be avoided. Here the aim should be to drill the required net of wells before too large an amount of production has been taken out of the reservoir and pressures have dropped to the point at which loss of productivity

becomes apparent, due to the difficulty of cleaning the mud sheath from the face of the formation and eliminating the "water block" caused by the penetration of water filtered from the mud into the pore space surrounding the well bore.

The field should be produced in such a manner that a reasonably uniform state of depletion prevails over the entire area, or, if separated into segments by impermeable barriers, each individual block, as determined by periodic "closed in" reservoir pressure surveys.

By this means loss of reservoir energy due to the transfer of fluids from areas of high pressure and little depletion to areas of low pressure and high depletion will be reduced to a minimum and the longest possible natural flowing life of the wells will be obtained.

A most useful guide in deciding the distribution of production among wells and of assessing the relative permeability of various sections of the reservoir is by comparison of their **specific productivity indices.** The productivity index of a well is defined as the **daily rate of production corresponding to unit bottom hole differential flowing pressure,** or daily production divided by "drawdown". It may be expressed in cubic metres per atm or more commonly barrels per lb per sq. inch. The specific productivity index is the above divided by the net sand thickness of the interval, expressed in metres or feet; it is a direct indication of the permeability of the formation immediately surrounding the well bore, provided flow of oil is not impeded by an inefficient screen or partially removed mud sheath.

To achieve reasonably equal rates of depletion, all wells should be produced at approximately equal drawdowns. Thus, the higher the productivity index the larger the permissible production rate.

This procedure must be subject to frequent checks of static reservoir pressure, however, because where there is a marked variation in the original oil content as between two sections of the same reservoir, equal rate of depletion will not be ensured by equal drawdown.

In the case of a well having an abnormally low productivity index compared to the field average, usually referred to as a tight well, it will be almost impossible to preserve equal differentials without restricting the well to what may well prove to be a commercially uneconomic rate of production. However, as the pressure drop will be largely dissipated at a short distance from the well bore, the consequences are only of local significance.

IV. Observation Wells

As a check on the efficient progress of the exploitation of a Type A reservoir, particularly with regard to the even encroachment of edge water and gas cap, it is very desirable to drill a certain number of what are termed "observation wells" at strategic points on the structure. These wells are not produced after their initial clean up. They are used to measure directly the rate of encroachment of the water table, the prevailing reservoir pressure under various rates of production from the other wells and to observe the pressure in the gas cap and its rate of expansion.

Water table observation wells are often available from those outstep wells which penetrate the water table within the productive layer, *cf.* Well G (Fig. 1). If specifically drilled for observation purposes, they should be located so that the oil/water level is initially near the base of the permeable section penetrated by the well, thereby giving the maximum effective observation life. Gas/oil contact observation wells should be situated as close as possible to the apex of the structure and should penetrate at least to mid oil column, if structurally possible, *cf.* Well D (Fig. 1). As the gas cap expands, downflank producing wells which have gone to gas

can take over the function of observation wells. Although at first sight it may appear an expensive proposition to those familiar with former oilfield technique to drill wells without intending to produce them, their value has been amply demonstrated in the prolific limestone fields of the Near East.

In fields with heterogeneous porosity, such as limestone reservoirs where it is difficult to determine the average porosity by laboratory measurements, the volumetric depletion of the oil column as determined in observation wells when compared to total oil extracted, forms the most reliable means of estimating the future recoverable reserves.

In Type B fields with closer well spacing, observation wells are usually not economically justified, since their application would be mainly of local significance. Here the preservation of a reasonably uniform state of depletion should be controlled by periodic surveys of the closed-in reservoir pressure in a reasonably large number of the normal producing wells. However, depending on the economic aspect, even in depletion fields, a number of wells may be kept closed in for continual observation of reservoir pressures under producing conditions.

V. Artificial Increase of Permeability

From preceding remarks it will be apparent that one of the most important properties constituting a favourable reservoir formation is good permeability. The permeability of the formation in close proximity to the bore hole is almost inevitably decreased by the process of "drilling in"; the degree to which this takes place is under the control of the engineer to some extent and can be minimized by use of chemically treated muds with good plastering properties and low water loss (filtration of water from the mud into the pores of the formation), or by the use of non-aqueous muds. Efficient washing to deplaster and clean the face of the formation and the well screen, if any, on completion of the well is equally important.

Acidizing; in the case of limestone reservoirs it is usually possible to restore the damage done during "drilling in" and also to improve upon the original permeability of the reservoir formation around the well bore by treatment with dilute (10 to 20 per cent) hydrochloric acid in which most limestones are relatively soluble. Treatments are made by injecting the acid into the formation, under pressure in quantities usually varying from 1000 up to 10,000 gallons dependent on the thickness of the section and its response to treatment.

Injection is often carried out in two or three successive stages with increasing quantities of acid at each stage or may be performed selectively over short sections of the total productive interval. Response varies considerably from well to well and field to field, but increases of productivity from such treatment up to tenfold have been realized.

Shooting. Since sandstones and siliceous cements are not soluble in hydrochloric acid, treatment is not possible by this method, though some success has been achieved by introducing a proportion of hydrofluoric acid together with the hydrochloric. In general, however, in hard or reasonably compact cemented sandstones, increases of productivity may often be achieved by exploding a charge of liquid nitroglycerine or nitrocellulose explosive in a well after having taken precautions to protect the water string casing by such means as a gravel, cement, or plaster of Paris tamping plug. This method of improving permeability may also be applied in limestones either separately or in conjunction with acidization.

VI. Pressure Maintenance and Secondary Recovery Methods

In those reservoirs which do not have sufficient inherent energy to recover a

high proportion of the oil originally present, it may be possible to increase the ultimate recovery by artificial measures taken to restore the reservoir pressure or to maintain it at a constant figure commonly known as "Pressure Maintenance". This is possible by (*a*) recompressing the gas liberated in the surface separators and returning it to the reservoir or (*b*) artificial stimulation of a water drive by pumping into the edge water or bottom water zone immediately below the oil column.

Apart from the addition of energy to the reservoir, reducing the necessity for artificial lift, maintenance of pressure also has the advantage of preserving the viscosity of the reservoir liquid at a lower figure—viscosity increases appreciably on liberation of gas—and minimizing the increased resistance to flow of reservoir liquid caused by the presence of free gas in the pore space. Free gas greatly reduces the permeability of the formation to liquid and, above a certain saturation, allows the gas to flow at differentially higher rates through the formation, until a gas saturation is reached (around 30 to 35 per cent) at which oil flow becomes negligible, leaving depleted oil behind in the reservoir.

The decision whether or not to incur the expense of such schemes can only be made after the reservoir has been producing for sufficient length of time to determine its production characteristics.

If the reservoir and economic circumstances are favourable, then the choice may lie between artificially stimulated water drive or gas injection. In the case of gas injection there must be sufficient gas available to reoccupy the reservoir volume voided by the production, or, if pressures have fallen to an undesirably low figure, to restore this at least in some partial degree. High structural relief, low free gas concentration, and uniform permeability are all factors favourable to gas reinjection schemes since the most frequent cause of failure is due to excessive by-passing of the injection gas to the producing wells. Gas may be returned direct to the gas cap or may be spread over the reservoir at wells intermediate to those from which the oil production is being taken.

For water drive, a plentiful source of water which will not be excessively expensive to purify for injection is essential (water must, if necessary, be treated so that it will not clog the sands). Sands should not be too argillaceous, or swelling of the shale on contact with water may reduce permeability; structural relief is not so important and the undertaking can be commenced with success when reservoir pressures have fallen to a much lower figure than with gas drive due to less liability of by-passing. The entry of loose sand in the producing wells and the necessity, in the later stages, of lifting large quantities of water with the oil are drawbacks to this method.

In heterogeneous reservoirs such as fractured limestones or sandstones having also a certain degree of primary porosity, associated with low permeability, the fractures form a network of laminar conduits of small volume compared to their areal extent, which present large flow surfaces to the oil from the low permeability blocks, while affording it highly permeable communication with the well bore. In such cases careful consideration must be given to a pressure maintenance scheme because, if pressures are maintained relatively close to the original, there will be a correspondingly small differential under which the oil from the primary porosity is produced into the fractures. Oil flow from the blocks of low permeability formation would then be retarded and may eventually be cut off by encroaching edge water. This possibility must be weighed against that of having to adopt artificial lift when the reservoir pressure declines. Dependent on circumstances, pressure

maintenance may be undesirable or there may be an optimum reservoir pressure at which flowing production can be maintained and yet a sufficient pressure differential will be available to recover a reasonable proportion of the oil from the primary porosity.

When the primary or "natural" phase of production from a reservoir has been completed or nearly completed, then methods for obtaining further recovery are usually referred to as "Secondary Recovery Methods". They are basically the same as for "Pressure Maintenance" except that restoration of reservoir pressure is not intended, but production is dependent on the ability of the gas or water to drive the recoverable oil into the near-by wells. Water flood wells may be placed on the periphery of the oil zone but more commonly are interspaced, usually on a "five spot" pattern among the producers.

CONCLUSION

The foregoing is a simplified outline of the more important principles of reservoir engineering; presented, it is hoped, in terms that can be readily grasped by those of scientific background not intimate with this particular aspect of the petroleum industry. Many complications arise in nature; with so many possible variables and the difficulties connected with subsurface measurements in high pressure wells, considerable practical experience, as also facility with advanced mathematical and physical concepts, are required in the elucidation of reservoir problems. Laboratory research is also continually taking place to supplement and improve our knowledge of the problems mentioned in this paper.

The author wishes to express his indebtedness to the Bataafsche Petroleum Maatschappij for permission to publish this paper.

SYNTHETIC LUBRICANTS

AT their annual meeting in June 1947 the A.S.T.M. Committee D 2 organized a symposium on synthetic lubricants. Three papers were presented: "'Ucon' Synthetic Lubricants and Hydraulic Fluids", J. M. Russ, Jr. (Special Products Divn., Carbide & Chemicals Corpn.); "Synthetic Lubricants from Diesters", F. J. Glavis and H. R. Stringer (Rohm & Haas Inc.); "Synthetic Lubricants for Military Aircraft", C. C. Singleterry (Bureau of Aeronautics, Navy Dept.).

These three papers and the discussions thereon are now published in a 33-page booklet, copies of which are obtainable from the offices of the Institute (6*s.* 6*d. post free*) or from the A.S.T.M. ($1.00 *post free*).

NORTHERN BRANCH COMMITTEE

OFFICERS and Committee for 1948–9 of the Northern Branch of the Institute is: *Chairman*, E. J. Dunstan; *Deputy Chairman*, T. W. Ranson; *Hon. Treasurer*, E. R. Wilson; *Hon. Secretary*, Mervyn Mason; *Committee*, C. E. Burnett, V. M. Farrant, A. J. Featherstone, J. E. Haslam, T. G. Provest, W. A. Ruffell, J. C. Wood-Mallock, A. W. Wooldridge.

Iranopol is the name of a new detergent developed by the research departments of the Anglo-Iranian Oil Co. Ltd., and Scottish Oils Ltd. It will be made at the Pumpherston refinery of the latter company and will be distributed by Irano Products Ltd. in packages ranging from glass bottles to 40-gallon barrels.

ECONOMIC UTILIZATION OF FUEL OIL IN BOILER AND INDUSTRIAL FURNACES*

By ARNOLD PEARCE

FURNACES FOR OIL FIRING

However successful a burner may be in efficiently atomizing the fuel, it is equally important that the combustion chamber should be suitably designed to assure that every particle of oil is burnt and maintenance reduced to a minimum.

Common sense, together with a sound theoretical and practical knowledge of the fundamental principles underlying combustion, will produce the best results, but in cases where the furnace has previously been designed to burn another fuel and dimensions are mostly fixed, there is not a great deal which can be done, except to see that the burners are positioned in such a way that flames cannot impinge directly on brickwork and that the air register and burner housing is constructed to give good mixing of the fuel and air. In small furnaces combustion rates of the order of 80,000 to 120,000 B.Th.U/cu ft/hr are quite normal, but heat release rates as high as 500,000 B.Th.U/cu ft/hr are exceeded in special cases. In large boiler furnaces for land use, combustion rates are generally kept on the low side, at or around 30,000 B.Th.U/cu ft, especially on units equipped with water walls and fed with a large percentage of treated water.

In oil refinery furnaces combustion rates are generally low in comparison with those employed in other industries. In this case it is mostly a question of heat absorption, since oil has a specific heat of only half that of water and about one-tenth latent heat. Thus, as a rule, combustion rates of about 10,000 B.Th.U/cu ft/hr are not generally exceeded.

Providing the heat released from the fuel can be absorbed without excessive overheating of the furnace walls, heavy heat loadings have certain advantages, such as the reducing of weight and space, and limiting the number of burners in operation. In a boiler furnace, for instance, to maintain a reasonably high ratio between capacity and heat absorption the best form of chamber is shaped long and narrow, so as to limit the exit temperatures of the gases leaving the furnace. But with burners placed horizontally a high furnace, as employed in coal-fired boilers, is not essential. It is only necessary to ensure that the generating tubes are kept well clear of oil or gas burner flames when the flame angle is a maximum. In industrial furnaces the shape and size and overall dimensions will largely be influenced by the type of processes being undertaken; and flame control and adjustment of the rate of combustion are mostly more important than anything else. Here, of course, the chief function of the furnace is to produce a satisfactory product, and in practice all other considerations must, of necessity, be subordinated to this.

In quite a number of industries the intense radiation from oil flames and ease with which flame traverse and luminosity can be controlled, has actually resulted in higher furnace efficiencies. This is true in the metallurgical industries, where conversion from coal to oil burning since the cessation of hostilities has proceeded at a phenomenal pace.

From the point of view of efficiency it is roughly estimated that about half a ton of oil is capable of giving about the same output from an open-hearth furnace as one ton of coal

* Concluded from p. 207.

previously gasified in producers. In addition, there appears to be a reduction in maintenance and other operating costs in favour of oil firing. It is possible that greater savings will be made when furnaces can be specially designed to burn oil, and not merely converted, as at present.

As in the United States it appears, therefore, that oil will replace producer or other coal gases to quite a large extent in the manufacture of steel in open-hearth furnaces, and in many other processes such as the reheating furnaces, soaking pits, and mill furnaces, where in the past the industry has depended upon, more or less entirely, coal (except for a few processes).

In boiler furnaces a factor of great importance is to ensure that the flame traverse is kept well clear of the water wall or steam generating tubes, as rapid failure of tubes will take place if this is not observed. This is particularly important where the treated water make-up is a high percentage of the total feed, and many engineers are adverse to employing bare water walls in such cases and often prefer to retain a normal type of refractory wall which may be either air- or water-cooled.

In the author's opinion it is preferable to retain some water cooling of the walls and partially shroud the tubes in either fire-brick or suitable tiles. Alternatively a refractory band placed in the combustion zone ensures a hot furnace in the vicinity of the burners, assisting combustion and reducing to some extent deleterious effects from flame impingement.

Such methods have been proved to be very effective in improving the performance of a sensitive boiler and reducing steam water velocities in the tubes, so that a higher quality of steam production can be obtained. Refractory maintenance should be negligible, as the water-cooled surface in contact will tend to reduce surface temperatures. If Bailey block or other similar types of furnace walls are employed these should be preferably provided with special refractory surfaces in the combustion zone, but in normal circumstances ordinary refractory tiles are quite satisfactory.

Should it be thought desirable to retain bare tube walls then it is essential that the burners be installed in the chamber well clear of the tubes on all sides. A minimum of 12 ft between front and rear walls is a good figure to work to. At the sides at least 4 ft should be allowed between wall face and centre line of burner.

It may be observed at this juncture that in marine boiler furnaces combustion rates as high as 300,000 to 500,000 B.Th.U/cu ft/hour may be reached, there being no refractory covering surfaces on the outer wall tubes whatsoever. In this case the quality of feed water is usually good, and up to central power station standards. It is worth mentioning that rates of combustion exceeding 2,000,000 B.Th.U/cu ft/ft are being obtained in gas turbine combustion chambers.

To enable a better picture to be obtained of the advantages of fuel oil from the point of view of furnace efficiencies, Fig. 11 gives an approximate comparison of the available heat from oil fuel and producer gas for different temperatures of gases leaving the furnace.

The effect of pre-heat of course raises the percentage of available heat. For instance, if we assume that 50 per cent of the heat in gases leaving at 2500° F can be recovered as preheat in the recuperator or regenerator, then the available heat becomes approximately the same as when the leaving gases from the furnace are at about 1400° F.

If we take into account producer efficiency, which under average conditions would be approximately 80 per cent, the position as regards utilization of fuel oil is even more favourable.

However, this latter reasoning is not

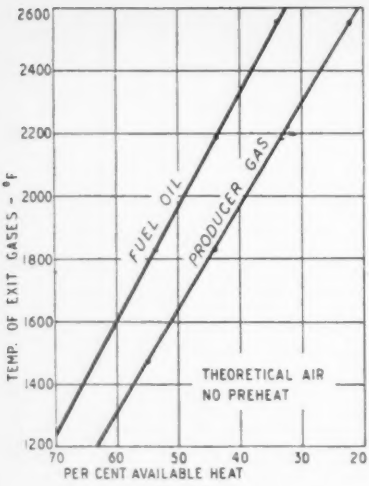


Fig. 11

strictly fair to other fuels since fuel oil must first of all be processed in a refinery having, say, an overall efficiency of not more than 80 per cent. Nevertheless, it is possible to obtain very much higher outputs from furnaces fired with oil, and particularly in those cases where processes require high temperatures. Fig. 12 illustrates approximate temperatures that may be attained with fuel oil and producer gas, the excess air in both cases being of the order of 15 per cent.

Flame temperatures may be calculated with a fair degree of accuracy, but at higher temperatures than 3000° F account must be taken of the dissociation of carbon dioxide and water vapour.

Dr Underwood has developed a graphical method which simplifies considerably the very laborious calculations required and these charts are very useful when determining flame temperatures under varying degrees of air preheat.

The intense radiation from oil flames, due in part to small particles of carbon and from carbon dioxide and water vapour present in the products of combustion, has an important bearing on its ability to transfer heat.

According to the Stefan Boltzman law, radiation is proportional to the fourth power of the absolute temperature, and this relationship is important in determining heat transfer by radiation.

A convenient form of expression for use in such calculations is:

$$R = KA\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right].$$

Where R = Radiation, B.Th.U/hr.
K = Emissivity factor.
A = Area of cold black body, sq. ft.
T_1 = Temperature of hot body, °F absolute.
T_2 = Temperature of cold body, °F absolute.

The practical application of this formula depends on the right choice of the emissivity factor K which, for theoretically perfect conditions, becomes 0·1723. Where heat transfer takes place to bare steel tubes this factor has a value approximately equal to 0·1640.

It is hardly necessary to add that satisfactory performance from a furnace also depends to a large extent on the provision of refractory materials of suitable quality.

Generally speaking, a high grade brick should be employed in all furnaces designed for oil or gas firing. Decomposition of hydrocarbon gases and deposited carbon on the fire-brick appears to effect rupture of the pores of the brick, finally bringing about disintegration and destruction. Spalling is also likely to occur due to rapid heating. Silica bricks are liable to spall

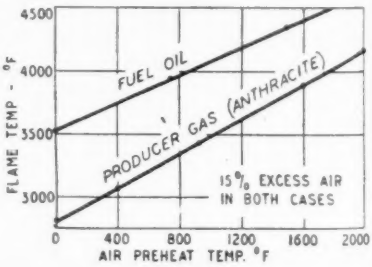


Fig. 12

as most of the expansion takes place below about 1500° F, so that such bricks should never be employed in furnaces fired intermittently. It is generally desirable that, for oil firing, refractories should contain a high percentage of alumina (i.e. over 40 per cent Al_2O_3), and a brick meeting this specification should have approximately the following properties for most requirements.

Seger-Cone	30/40—3000/3500° F
Cold crushing strength	2500 p.s.i. min.
Density	29 to 52 lb. cu. ft.
Porosity	75 to 85 per cent
Lime (Ca0)	not more than 1·0%
Magnesium (Mg0)	not more than 0·6%
Iron (Fe_2O_3)	not more than 2·5%
Soda (Na_2O) Potash (K_2O)	not more than 2·0%

Where very high temperatures are reached materials such as corundum, silicon, carbide, sillimanite, and others may be employed.

High quality bricks are normally only required as a facing brick so that for backing bricks sheltered behind fire-bricks a refractoriness approximating to cone 6a/18 should normally be sufficient as the heat insulating properties of the latter will be most important.

SOME PRACTICAL RESULTS OF COAL-OIL CONVERSIONS IN INDUSTRY

QUOTING from an authoritative source it is reported that open-hearth furnaces in South Wales converted to oil or tar burning have increased their average weekly output from 9000 to 11,000 tons. The open-hearth furnace can be considered as a very good oil conversion, since under normal conditions one ton of oil will replace two tons of coal. In addition, mill furnaces in tinplate works have also proved good conversions, with an increase in output of at least 10 per cent in most cases.

Another very striking example is provided by a sheet steel works. Before the conversion, coal consumption worked out at approximately 5 cwt per ton of sheet for a total production of just under 100 tons a week. On conversion the furnaces were reconstructed to take full advantage of oil fuel, and oil consumption worked out at approximately 150 lb a sheet, giving a coal to oil parity of at least 3·75 to 1, and an increase of output to approximately 130 tons per mill.

In many other industries (non-ferrous, ceramics, etc.) similar results have been achieved, together with a great improvement in the processing of the material and in working conditions for the operators. These cases show the importance of utilizing the right fuel in its best sphere of application.

FUTURE DEVELOPMENTS IN OIL BURNING

It is difficult to forecast with any exactitude, developments in oil burning apparatus and the use of oil in industry. The remarkable results that have been achieved by conversion from coal to oil burning in recent times will probably influence future policy and result in increased use of oil, particularly in those industries where oil burning has achieved large increases in output. It is possible that developments in the near future, some of which may be traced to the recent progress in the manufacture of cheap oxygen in the U.S.A., may bring the process of obtaining oil from coal and its derivatives more within the economic range of imported oil.

It is unlikely that great changes will take place in the processes of burning oil in furnaces, but there is still a good deal of scope for development of existing burner types to improve range of output and classes of fuel that can be burnt efficiently, while retaining the simplest possible design features, both in regard to construction and control, with the need for the minimum amount of attention.

The mechanical atomizing burner has become more and more popular for the larger outputs and this type of burner is continually being improved in regard to working range and output. In practice

a range of 5 to 1 is generally sufficient for most purposes, but a burner of this type can now be supplied with a range of 20 to 1, or greater if desired. For the latter duties, atomizing pressures have to be increased and an installation operating with an oil pressure in the region of 950 p.s.i. is already working in America, but for more normal requirements pressures in excess of 450 p.s.i. are usually not necessary. One of the chief requirements for burners operating at these high pressures is that materials of which the atomizer is constructed must withstand severe erosion of working surfaces, particularly if the oil is not highly filtered. While tungsten carbide is admirably suited for these purposes, its present cost prohibits its use on a large scale, so that the problem becomes mainly a question of the life of the working parts versus initial cost.

While coal remains the chief source of fuel in the U.K. there is little prospect that fuel oil will oust other fuels for firing boilers, except in a few special cases. In certain industries its use will possibly be extended.

COST OF OIL BURNING

With equipment, labour, and material costs varying so much it is not possible to give more than an approximate comparison of the capital cost of installing oil-burning plant. For three sizes of plant the figures are:

Size	*Fuel consumption, ton/hour*	*Approx. capital cost per ton of oil consumed per year**
Large	25–30	2s. 6d.—3s. 0d.
Medium	10–12	4s. 0d.—4s. 6d.
Small	2–3	5s. 0d.—6s. 0d.

* Excluding erection but including all burner equipment pipework, heating and pumping units, and tankage for 2 to 3 weeks' fuel supply.

As regards the operating cost of various types of burners, this again varies with size of installation, fuel cost, and depends on various site factors outside the consumer's jurisdiction. In large efficient installations, and employing mechanical atomizing, the cost of pumping, heating, etc., may only amount to a few pence per ton of oil consumed, but in others of the smaller type where low pressure air or steam is employed for atomization, the operating cost may be of the order of a few shillings per ton of oil consumed, particularly in those burners where all the air for combustion passes through the burner.

High pressure steam or air lower the cost somewhat since only 2½ per cent or less of the high pressure medium is required for atomization and the remainder required for combustion can be fed to the furnaces at more normal air pressures.

Finally, it should be stated that before proceeding with the installation of oil burners for steam production or furnace work it is very advisable to discuss the matter with the makers, and other experts, who know exactly the limitations of their burners and from previous experience can judge the best type of equipment to install to meet the special conditions under which the plant may have to work.

The author is indebted to the National Oil Refineries Ltd. and Messrs Peabody Ltd. for loan of demonstration models, etc., and his thanks are due to Messrs Wallsend Slipway & Engineering Co. Ltd., Laidlaw, Drew & Co. Ltd., and Todd Oil Burners Ltd.

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JAMES YOUNG—FOUNDER OF THE MINERAL OIL INDUSTRY*

By EDWIN M. BAILEY (Member)

James Young's scrap-books of newspaper cuttings are full of interest; they contain a series of seven long articles on "A new Industry, or the Mineral Oil Manufacture" (from *The Morning Journal*, 1866); Reports of the London, Irish, and Paris Exhibitions, with accounts of his exhibits and awards; many cuttings from American papers in 1866; and in 1862 from many British ones about the danger of mineral oils in lamps—Young contending that these were not *his* product or if sold as his were adulterated, and claiming that "no single explosion has ever taken place in all the 10 years of all the thousands of lamps burning Young's patent paraffin oil." Dr Angus Smith reported that, "Young's oil will not ignite in an open vessel at 154° F, whilst a sample of American rock oil sold as paraffin exploded at a temperature of 46° F."

There are interesting and amusing advertisements of his oil by dealers. *The Glasgow Herald*, 1858—"Young's Paraffin Oil Lamp for 4*s*. to 30*s*.: Oil, 3*s*. 6*d*. per gallon." Some advertisers, like Silas Wegg in *Our Mutual Friend*, drop into poetry, thus:

"And that which Watson sells to me
He has from Young the Patentee."

Here is another specimen:

"And what makes it still more important
to tell,
The Paraffin Oil that E. Watson doth
sell,
Supplied is by Young, the renowned
Patentee,
And hence from explosion and danger
is free."

There is an article on "The Last of the Arn's Well Trees" on Glasgow Green, where he used to walk (*Glasgow Herald*, 1857): and a "Hotel Menue and Wine List—St. Nicholas Hotel, New York"—supplying anything "From Chowder to Pop Corn", and 130 named or dated brands of Wines, Spirits, Ales, and Porters!

There are 25 cuttings about the reported death of Dr Livingstone in 1867 that turned out to be false rumours.

Let us now turn to his personality and character as viewed by his friends. To Lyon Playfair, "He was a raw youth when I first knew him and was a most intelligent companion. Livingstone, Young, and I were Graham's favourite pupils."

As a young man he stood out in Angus Smith's memory "chiefly as a head sufficiently red and uncombed, by no means like the smooth yellow hair of his middle age, or the venerable white of his later years". But he remembered him spoken of as "a very remarkable individual." Livingstone referred to him as "a valued private friend."

To others he appeared as "a dark, wiry lad with a somewhat cool and cynical temperament", "a silent and undemonstrative man": his opinion having "a determined flavour of independence and originality, but he was neither self-assertive nor dogmatic."

We may take the following from the tributes in the newspapers of May 1883, when his span of life was ended:

"By the death of Dr Young, a remarkable career has closed, and Glasgow has lost one of the most eminent and widely known of her citizens." (*Glasgow Herald*, May 15, 1883.)

* Continued from page 221.

"By the death of the distinguished chemist, Scotland loses one of the most racily vernacular of her recent worthies . . . as rugged in his way as Carlyle himself, and as pronounced in his aversion to all pretence and sham.

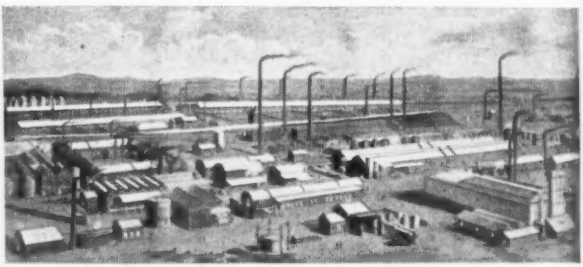
"At the Working Mens' Flower Show . . . the chairman said that Dr Young had been one of the earliest and most liberal supporters of their efforts to foster a taste for floriculture among the working classes of the city. The collections of rare and choice plants from the Kelly conservatories had always been the leading feature of their association. They had lost one of their most distinguished and devoted friends: while in the field of industrial science and commercial enterprise and activity few names stand higher than that of Dr James Young.

"His mind took nothing for granted. His belief rested on definite promises, which he had sifted as carefully as any experiment in science. . . . There was a quiet decision in his profession of Christianity," so in his changes of residence "he resorted to the congregation, whatever the church to which it belonged, established or dissenting, where he found the doctrines of the Gospel most faithfully and earnestly preached.

"The chief beauty, in all his attainments and in the spirit with which he contemplated his own success, was his habitual and intense satisfaction in the degree to which his discoveries swelled the sum of human comfort. Every public measure which tended to the relief of the lowlier classes of the community had his warm support. Under an exterior hardened somewhat by the severe and anxious struggles of early life, and by reliance upon his own energies, there was in him the central warmth of a genuine humanity, ever alive to human suffering and eager for its relief. . . . Whatever threw open the gates of knowledge to the humblest, whatever tended to reward and encourage honest industry, had his cordial approval.

"He leaves a name that is universally honoured and respected." (*New York Herald*, May 15, 1883.)

"He has been no less distinguished for his public spirit and munificence



[Courtesy The A.P.O.C. Magazine

The Addiewell Works in about 1870.

than for his eminence as a technical chemist." (*Chem. News.*)

"With unimpaired memory for the past, he was as keenly alive as ever at the close of his life to the questions of the day, to all the discoveries and especially to the inventions which were making, and he was finding out quite new directions in which his love for chemistry was displaying itself. Only those who had the opportunity of hearing his views can guess what he might have ultimately done in helping its progress in directions still neglected in this country." (*Memoirs and Portraits of One Hundred Glasgow Men.*)

When the marble bust of Dr Young was presented to Glasgow Royal

Technical College in 1907 by his daughter, Mrs Walker of Limefield, West Calder, Mr G. T. Beilby (later Sir George), said: "they were unable to express their deep and sincere conviction that in the personality of Dr Young, the College possessed a moral and intellectual asset which was to be rated far above any merely material benefit they owed to him. The long and close association of Dr Young with the College, his high scientific and technical attainments, and his brilliant success as an industrial pioneer, all combined to give to his memory an honoured place among the sacred heritages of the College."

To confirm Young's continued interest and powers of observation, I quote from his diaries of 1874 and 1875. On a visit to Egypt: "One buffalo works 3 hours at a time—depth of well, 17½ feet—raising 35 pots of water in a minute. Temperature of Nile taken out of the paddle in motion, 14 cent." At Italy, in 1875: "The solder joints of the lead pipes in the Pompeii inn house in a palace of the Caesars contained tin; Viaticum, a little tin; Lateran metal, no tin. Sunday at church twice. Met Sir James Watson and White the chrome man. Garibaldi good, good man. May the Giver of all good be with him." (In this diary there is a note: "Picture of old Bryson.")

"Jan. 1, 1874. Langham Hotel. Sir Bartle Frere called. Told him I would bear all the expense of Grandy's expedition."

Rev. Florian Waller, London: "Arrange to bring Chuma and Susi to London. I will pay cost. Young."

No great place in Young's life appears to have been found for sport or recreation, if we except the weekly walks of his youth, reading and book-collecting, and in his later years yachting—and what finer combination could there be for refreshment of body and of mind? In 1872 he took his old friend Angus Smith on cruises to St Kilda and to Iceland in his yacht the "Nyanza", and accounts of these voyages were printed by Smith. In 1880 he took Prof and Mrs Thomson and Dr W. B. Robertson in his yacht to the Hebrides, and "shipped Angus Smith at Tobermory". He did a good deal of yachting on the Clyde.

He was of a modest and retiring nature and he evidently did not "love the limelight".

From the old days at Manchester his political faith and zeal never lost their flame. "In politics an ardent Liberal, he took a keen interest in the election of Gladstone for Midlothian, and delivered a spirited little speech as chairman of the meeting at West Calder in the afternoon preceding the memorable contest of 1880."

It is evident from his diaries that he was in his youth a very regular attender at Church, and he did not desert this practice in his mature years; at any rate it is on record that "in 1852, while resident in Edinburgh, he joined Martyrs Reformed Presbyterian Church, and on his removal to the West, he became a member of Great Hamilton Free Church, Glasgow." On his travels in France, Italy, U.S.A., and Egypt, he attended church regularly.

His youthful diaries and the widely varied contents of his scrap-book reveal his industry and activity, his keen powers of observation, his zest for life, and his many-sided interests; and they present to our minds one who, even in youth, took the art of living with a grave seriousness and serenity, lit up with and balanced by many gleams of naïve humour and a great delight in innocent and simple "fun". His was no morbid, brooding, pessimistic mind; he was no narrow, self-centred "specialist", no "Dr Dry-as-dust". He had the true broad scientific outlook and catholicity; the spots on a chicken; a Channel Tunnel; the preserving of cuttings like "The Leadhills of Scotland and the Manufacture of Lead", and a poem

"The Wee Orphan Laddie", and his interest in the collection of his magnificent library of alchemical and other books—all these and far more came within the compass of his inquiring spirit and alert intelligence.

For his work as a technical chemist and industrialist, his monument is the industry he founded, and as for his capacity as "a business man" (whatever that may mean!) the technical, commercial, and financial success of his undertakings are outstanding witness.

His foresight, perseverence, pluck, and tenacity of purpose were shown in his protracted struggle in defence of his patent rights.

For the public spirit and generosity that characterized him we have only to recall his munificence in gifting the Chair of Technical Chemistry and its great library, and his lavish disbursements in aid of the African expeditions.

In 1876 he gave £100 to The Chemical Society's Research Fund: and in 1878 £1000 to the Royal Society.

Dr Young originated the movement for the erection of the statue of Livingstone in George Square, Glasgow. There also stands the statue of Prof Thomas Graham, erected at Young's expense and presented to the City of Glasgow.

He collected all Graham's memoirs into one volume for presentation to the Professor's friends and other chemists. He was also instrumental in producing *The Life and Works of Thomas Graham*, by Dr R. Angus Smith. He presented to the Royal Technical College, Glasgow ("Young" Chair), his magnificent collection of 1300–1400 alchemical, chemical, and pharmaceutical books—many of them very rare and valuable historically. He also engaged John Ferguson, Prof of Chemistry, in Glasgow University (affectionately, if familiarly, known as "Old Soda"!) to prepare a catalogue of this fascinating library, and this was printed in 1906, with the title *Bibliotheca Chemica*, for private distribution by Young's family. In his most interesting introduction to the Catalogue, Ferguson says that the collection was begun by Young himself about 1850.

The great chemist, Michael Faraday, when a young man, drew up the following ideal portrait:

"The philosopher should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biased by appearances, have no favourite hypotheses, be of no school, and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities be added industry, he may indeed hope to walk within the veil of the temple of Nature."

Surely, in no small measure indeed, may this be said of James Young.

After a period of failing health, on May 13, 1883, in his 73rd year, James Young, Dr Young of Kelly, laid down the burden of his years of strenuous yet happy labour and passed away from the mortal scene in his home at Kelly, survived by three sons and four daughters. On the Sunday following his funeral, Dr Wm. B. Robertson of Irvine preached at the evening service in Skelmorlie United Presbyterian Church, from the text, "Christ hath brought life and immortality to light by the gospel".

In the secluded, peaceful little resting-place above the parish church in the beautifully situated village of Inverkip, some miles from Kelly, there is a memorial stone, facing the sunshine of the south, and bearing the simple yet adequate inscription:

"In Memory of James Young of Kelly,
F.R.S., LL.D.,
Born 1811. Died 1883.
The righteous and the wise and their works are in the hand of God."

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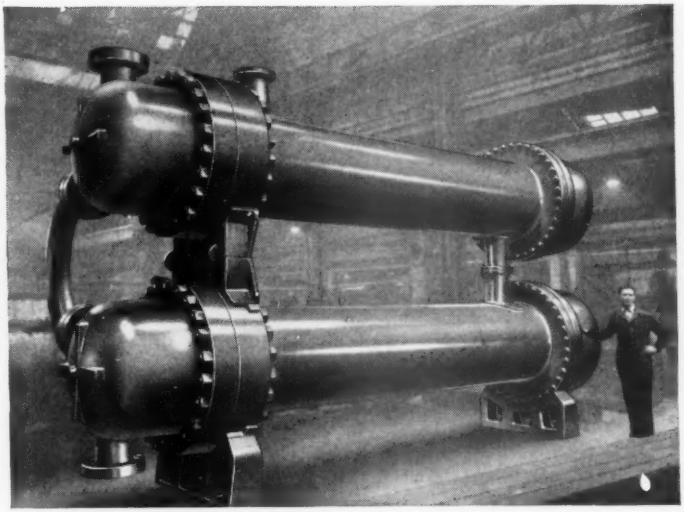

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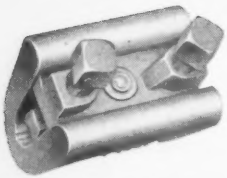

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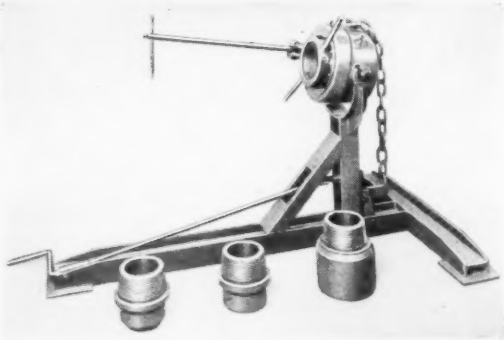

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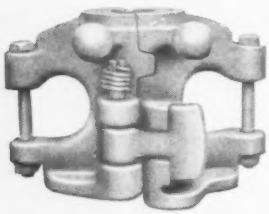

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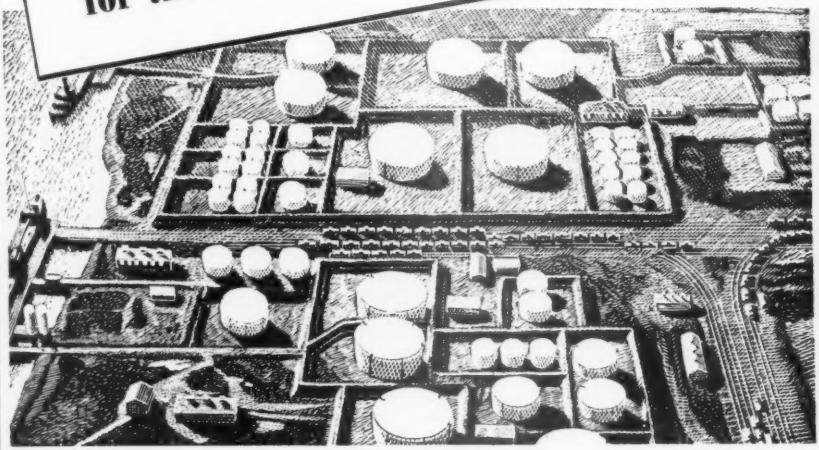

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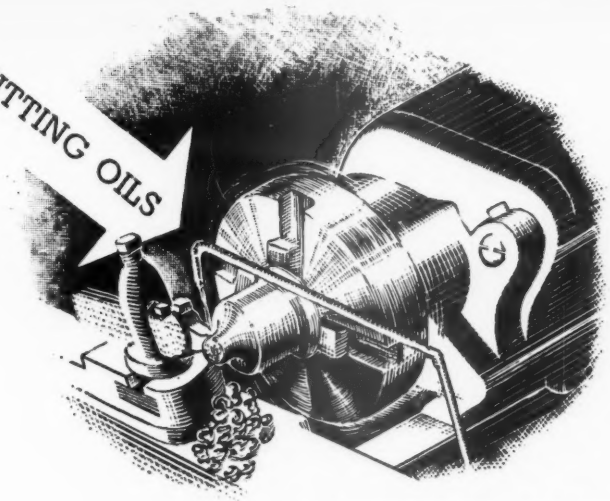

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